

Combined aircraft and satellite-derived storm electric current and lightning rates measurements and implications for the global electric circuit.

Using rotating vane electric field mills and Gerdien capacitors, we measured the electric field profile and conductivity during 850 overflights of electrified shower clouds and thunderstorms spanning regions including the Southeastern United States, the Western Atlantic Ocean, the Gulf of Mexico, Central America and adjacent oceans, Central Brazil, and the South Pacific. The overflights include storms over land and ocean, with and without lightning, and with positive and negative fields above the storms. The measurements were made with the NASA ER-2 and the Altus-II high altitude aircrafts. Peak electric fields, with lightning transients removed, ranged from -1.0 kV m^{-1} to $16. \text{ kV m}^{-1}$, with a mean value of 0.9 kV m^{-1} . The median peak field was 0.29 kV m^{-1} .

Integrating our electric field and conductivity data, we determined total conduction currents and flash rates for each overpass. With knowledge of the storm location (land or ocean) and type (with or without lightning), we determine the mean currents by location and type. The mean current for ocean storms with lightning is 1.6 A while the mean current for land storms with lightning is 1.0 A . The mean current for oceanic storms without lightning (i.e., electrified shower clouds) is 0.39 A and the mean current for land storms without lightning is 0.13 A . Thus, on average, land storms with or without lightning have about half the mean current as their corresponding oceanic storm counterparts. Over three-quarters (78%) of the land storms had detectable lightning, while less than half (43%) of the oceanic storms had lightning. We did not find any significant regional or latitudinal based patterns in our total conduction currents. By

combining the aircraft derived storm currents and flash rates with diurnal lightning statistics derived from the Lightning Imaging Sensor (LIS) and Optical Transient Detector (OTD) low Earth orbiting satellites, we reproduce the diurnal variation in the global electric circuit (i.e., the Carnegie curve) to within 4% for all but two short periods of time. This excellent agreement with the Carnegie curve was obtained without any tuning or adjustment of the satellite or aircraft data. Given our data and assumptions, mean contributions to the global electric circuit are 0.7 kA (ocean) and 1.1 kA (land) from lightning-producing storms, and 0.22 kA (ocean) and 0.04 (land) from electrified shower clouds, resulting in a mean total conduction current estimate for the global electric circuit of 2.0 kA. Breaking the results down into mean storm counts reveals 1100 for land storms with lightning, 530 for ocean storms without lightning, 390 for ocean storms with lightning, and 330 for land storms without lightning.